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Mediational Pathways of Mindfulness and Exercise on Mental Health and Perceived Stress: A Randomized Controlled Trial

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Abstract

This study investigated the effects of mindfulness and exercise training on indicators of mental health and stress by examining shared mediators of program effects. Community-recruited adults, (N = 413), were randomized into one of three conditions: (a) mindfulness-based stress reduction (MBSR), (b) moderate intensity exercise, or (c) wait-list control. Composite indicator structural equation models estimated direct, indirect and total effects. The results showed that mindfulness-based self-efficacy fulfilled a prominent role in mediating both meditation and exercise program effects. Our findings demonstrated that mindfulness and exercise training share similar mechanisms that can improve global mental health, including adaptive responses to stress.

Keywords

Mindfulness-Based Stress Reduction; Meditation; Exercise; Mental health; Perceived stress

Complementary and alternative treatments such as mindfulness meditation and exercise have been increasingly implemented within health care settings to reduce the burden of chronic health conditions linked to stress (Sarris et al., 2012). Within health care contexts, meditation (Kabat-Zinn, 1982) and exercise (Dubbart, 1992; Martin, 1982) aim to prevent acute or chronic conditions and to strengthen recovery from illness or injury. University of Wisconsin-Madison investigators tested mindfulness meditation and exercise training programs with participants at risk for acute respiratory infection (ARI), finding that both meditation and exercise training reduced ARI (Barrett et al., 2012). The current paper is based on data from the same randomized trial, assessing main effects of the training programs on indicators of mental health and stress, while also testing mediating mechanisms of effect.

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Mindfulness Meditation

Mindfulness meditation training has been growing rapidly in popularity in recent decades. For example, mindfulness programs that are designed to manage stress and promote well-being have been widely disseminated throughout health services (Kabat-Zinn, 2003). Current conceptualizations of mindfulness point to two essential elements: (a) awareness of one's moment-to-moment experience, with (b) a nonjudgmental and accepting mental perspective (Keng et al., 2011).

Although many mindfulness meditation programs drawing on traditional Buddhist practices exist in health care today, arguably the most validated and standardized of these approaches is Jon Kabat-Zinn's Mindfulness-Based Stress Reduction (MBSR) (Kabat-Zinn, 1993). A number of studies reveal that participation in MBSR outpatient programs confer an array of psychosocial benefits for patients with a range of medical conditions. For instance, MBSR has been shown to decrease mood disturbances and stress symptoms among patients with cancer and chronic diseases (Specia et al., 2000) and improve self-regulation for chronic pain patients (Kabat-Zinn, 1982). A number of meta-analyses examining the clinical efficacy of mindfulness-based interventions suggest that mindfulness is a promising intervention to treat a variety of psychological symptoms and disorders (Baer, 2003; Bohlmeijer et al., 2010; Hofmann et al., 2010) and to promote physical and mental well-being (Grossman et al., 2004). For example, MBSR has been shown to have a mitigating effect on depression and anxiety in patients with fibromyalgia (Grossman et al., 2007), women with multiple sclerosis (Kolahkaj & Zargar, 2015), and veterans (Serpa et al., 2014). Other mindfulness programs also appear to positively influence health-related outcomes such as stress and inflammatory response (Rosenkranz et al., 2013) and immune functioning (Barrett et al., 2012). Although mindfulness programs generally incur benefit for the practitioner, there are a small number of studies that show no effect on positive affect and well-being (Goyal, 2014).

Exercise

Exercise has been recognized for decades by the field of medicine for its relevance to health maintenance, disease prevention and rehabilitation (Bouchard, 1990). Most notably, sustained moderate to vigorous exercise ("cardio" or "aerobic" exercise) has been shown to significantly reduce the risk of coronary heart disease (CHD) (O'Connor, 1989), hypertension (Blair, 1984; Martin, 1990) and diabetes (Laws, 1991). Exercise can also promote brain plasticity (Cotman & Berchtold) and can improve cognitive functioning, increase executive control (Daly et al., 2014), and may buffer age-related cognitive decline (Weuve et al., 2004). Despite the fact that exercise has been shown to improve mood and mitigate depression and anxiety (Plante, 1990; Stephens, 1988), exercise has not been widely incorporated into the treatment of mental health problems (Callaghan, 2004).

Mediating Mechanisms of Mindfulness Meditation

There are a number of studies that suggest mindfulness may be a mechanism through which MBSR promotes positive mental health-related outcomes (Branstrom et al., 2010; Demarzo et al., 2014; Nyklík & Kuijpers, 2008; Salmoirago-Blotcher et al., 2013). Nyklík and

Kuijpers (2008) found mediation effects of general mindfulness as measured by the MAAS on perceived stress, quality of life and vital exhaustion among community participants with symptoms of distress (Nyklík & Kuijpers, 2008). Branstrom et al., (2010) indicated that the psychological improvements resulting from mindfulness training could be explained by increased levels of mindfulness among cancer patients (Branstrom et al., 2010). Additional research suggested that a change early in mindfulness treatment predicted an overall improvement in perceived stress among chronically stressed individuals (Baer et al., 2012).

Potential Mediating Mechanisms of Exercise

It has been shown that regular exercise can increase exercise self-efficacy (Gilbert, 2010; Kaplan et al., 1984) and improve mental health (Plante, 1990; Stephens, 1988). According to Stults-Kolehmainen and Sinha (2014), the bidirectional relationship of stress and exercise and their underlying mechanisms are not well understood (Stults-Kolehmainen & Sinha, 2014). Joseph Royse, Benitez, and Pekmezi (2014) revealed that exercise can improve quality of life outcomes through the mechanisms of self-esteem and emotion (Joseph et al., 2014).

Shared Mediating Mechanisms

Demarzo, et al. (2014), hypothesized that mindfulness levels may explain part of exercise program effects (Demarzo et al., 2014). Further, there may be a reciprocal relationship between mindfulness and exercise whereby exercise has been shown to increase mindfulness levels (Goldin, 2012) and, conversely, mindfulness may contribute to enhancing exercise training particularly on cardiovascular responses to stress (Demarzo et al., 2014). In the predecessor of this study, Zgierska et al. (2013) found that increases in mindfulness measured by the Mindful Attention Awareness Scale (MAAS) explained positive effects of meditation and exercise training on acute respiratory illness (Zgierska, 2013). The present study hypothesis is informed by a growing empirical base of literature, which posits mindfulness may share similar mechanisms with exercise that influence health (Demarzo et al., 2014; Goldin, 2012).

Objectives

The purpose of this study is to: (a) assess the influence of exercise and meditation programs on mental health and stress outcomes, and (b) identify and examine shared mediators through which both programs achieve mental health effects. Consistent with previous studies, we hypothesized that increases in mindful attention awareness, mindfulness self-efficacy, exercise self-efficacy and physical activity may be mechanisms through which mindfulness and exercise training can lead to improved mental health and perceived stress (Baer et al., 2012; Barrett et al., 2012; Demarzo et al., 2014; Goldin, 2012; Zgierska, 2013). While there are a number of studies suggesting that mindfulness skills are important mediators of MSBR (Baer et al., 2012; Branstrom et al., 2010; Demarzo et al., 2014; Nyklík & Kuijpers, 2008; Salmoirago-Blotcher et al., 2013), conducting longitudinal randomized trials to assess mediation represents the next frontier of this work. Validating mechanisms of effect with rigorous methods strengthens confidence in main effect findings.

Moreover, testing mechanisms that are shared between interventions yields implications for future programming (Gu et al., 2016).

To our knowledge there is no other published trial that included a control group, comparable stress reduction intervention groups, adequate sample size, and composite indicator structural equation models to assess the mediating mechanisms explaining the effects of mindfulness and exercise training on mental health and stress. Therefore, the unique contribution of this study lies in the design and statistical methods. We have some ability to conclude causality from mindfulness and exercise training to outcomes due to randomization and longitudinal data collection. Assessing change in mediating variables that precede change in outcomes provides more substantive and convincing results of treatment effects as compared to pre- and post-analysis (Kraemer, 2002). It also highlights pathways of effect, which can shape program design, e.g., enhancement of program elements.

Methods

Participants

Participants were recruited from Madison, Wisconsin, and surrounding areas via flyers, posters, and brochures posted in medical settings and in the community. The trial included four yearly cohorts, participating respectively from September through June, 2012–2016. Screening occurred in the summer, baseline assessment and randomization in August, and behavioral trainings in September and October. Participants were followed until May using computerized weekly self-report and daily self-assessments. Weekly self-reports included daily minutes of meditation and exercise practice, with minutes of meditation classified as formal or informal and minutes of exercise categorized as moderate or vigorous. Additionally, three standardized follow-up hospital lab visits for everyone occurred at UW Hospital and Clinics, Clinical Research Unit. During these scheduled visits nasal wash and blood for biomarkers of chronic inflammation were assessed.

Participants were women and men aged 30 to 69 years who reported at least one ARI per year on average. Individuals were excluded if they scored 14 or higher on the PHQ-9 depression screen (Kroenke, 2001), had a current practice or prior mindfulness training, exercised vigorously at least 1 time per week or moderately at least 2 times per week, had current or anticipated use of antibiotics, antivirals, immune active medications, malignancy or autoimmune disease. Each sequentially enrolled participant received the next sequentially numbered sealed envelope containing randomization codes generated by the study statistician using permuted variable-sized block randomization (SAS software). The key linking codes to intervention categories were blinded from co-investigators, study personnel and analysts until after the first stages of statistical analysis were completed. The trial was coordinated by the University of Wisconsin (UW) Department of Family Medicine and Community Health. The behavioral interventions were conducted at UW Research Park, a multipurpose outpatient clinic with exercise facilities and space suitable for meditation training.

Study Design

The present study is a randomized controlled trial (RCT) funded by the National Institutes of Health (NIH), National Center for Complementary and Integrative Health (R01AT006970) and some support from a Clinical and Translational Science Award (CTSA) through the National Center for Advancing Translational Sciences (NCATS), grant (UL1TR000427). Community-recruited adults were randomized into one of three conditions: (a) 8-weeks of training in mindfulness-based stress reduction (MBSR), (b) matched 8-weeks of training in sustained moderate intensity exercise, or (c) wait-list control. The primary aim of the RCT was to determine whether training in either intervention group could reduce acute respiratory infection (ARI) illness burden. Secondary aims were to test whether training in meditation or exercise could improve psychosocial and physical health indices, and to explore whether these changes could be partially or fully explained by mediating influences. The original protocol was approved by the University of Wisconsin Health Sciences Institutional Review Board. The full trial protocol (NCT01654289), which can be accessed at ([ClinicalTrials.gov](https://clinicaltrials.gov)) was conducted in accordance with the protocol approved by the NIH and was monitored by a data and safety monitoring committee.

To gain a better understanding of how meditation and exercise training affect mental health and perceived stress, we used a mediation analytic structure to examine direct and indirect effects, and specialized treatment effect pathways on expected outcomes of mental health and perceived stress (MacKinnon et al., 2007). The data comes from recently completed Meditation or Exercise to Prevent Acute Respiratory (MEPARI-2) trial, which was designed to replicate and extend findings from MEPARI-1 (Barrett et al., 2012; Obasi, 2012; Rakel, 2013; Zgierska, 2013).

Experimental Conditions

Mindfulness Meditation—Mindfulness meditation training consisted of an 8-week MBSR program, which included 2½ hour weekly sessions and regular at-home daily practice (Kabat-Zinn, 2003). Group sessions were comprised of exercises designed to increase awareness of physical, emotional, cognitive, and interpersonal responses to stress. Participants were asked to practice at home for 45 minutes per day and to log minutes of daily practice once weekly using an on-line data collection tool. The MBSR intervention was conducted by trained instructors with experience teaching MBSR at the University of Wisconsin Integrative Medicine Program.

Exercise—The exercise program, consistent with many standardized exercise programs (Kohut et al., 2005; Nieman, 2009; Perri et al., 2002), matched the meditation program in duration (8 weeks), attention (weekly 2½ hour group sessions), and intensity (daily 45 minute at-home practice). Exercise training consisted predominantly of walking or jogging. These were activities that were convenient, did not require special equipment, and could be practiced at home. The didactic portion included: review of the previous week's activities, brief presentation on exercise techniques and effects, discussion of behavioral change principles and strategies, and closure to discuss the following week's exercise goals and logistics. Participants recorded their exercise in minutes per day, and entered data once

weekly into an on-line data collection tool. Participants in the exercise group met at UW Health Sports Medicine Clinic for the 8 weeks and were trained by exercise physiologists.

Control—One-third of the participants were randomly assigned to a usual care wait-list non-interventional control group. Those in the control group were treated in the same manner as participants receiving mindfulness or exercise training, which included weekly email/telephone contact and monthly questionnaires. Control participants were offered free meditation training after they completed their study participation, assistance with finding appropriate exercise training, or \$300 cash. They were reminded of this occasionally throughout the study to help maintain adherence to protocol.

Measures

Participants completed several repeated, validated, self-report questionnaires. Measures were used to assess outcomes and to explore potential pathways that link meditation and exercise programs to those outcomes. Questionnaires were administered at baseline, 1 week post-intervention and alternating months thereafter. Data were collected with a temporal consideration for assessing mediation (Kraemer, 2008), which assumes a mediator (M) is assessed sometime after its presumed cause (X) and prior to the outcome effect (Y) (MacKinnon et al., 2007). Based on temporal precedence (Kraemer, 2001), mediating measures for this analysis were collected at 4 months (i.e., MAAS, GPAQ) and 6 months (i.e., MSES-R, ESES) post-intervention, and outcome measures were collected at 8 months post-intervention to assess for mechanisms of change. Global scores were created following recommendations of questionnaire authors.

Outcome—The SF12 is a 12-item version of the Medical Outcomes Study Short Form (SF36) that assesses overall health and provides algorithm-weighted general physical (SF12P) and mental health (SF12M) scores (Ware et al., 2008). The PSS is a 10-item version of Cohen's Perceived Stress Scale that has been linked to ARI outcomes, including influenza (Cohen et al., 1991). The PSS is the most widely used psychological instrument for measuring the perception of stress (Cohen & Janicki-Deverts, 2012).

Mediators—The Mindful Attention Awareness Scale (MAAS) is a 15-item measure of mindfulness (Carlson & Brown, 2005). The Mindfulness-Based Self-Efficacy Scale - Revised (MSES-R) is a 22-item measure of the self-efficacy of skills that develop as a result of becoming more mindful. MSES-R subscales related to mindfulness self-efficacy were assessed to examine the indirect specialized treatment effects on expected outcomes. The Exercise Self-Efficacy Scale (ESES) is a 9-item measure of exercise-related self-efficacy (Resnick & Jenkins, 2000). The Global Physical Activity Questionnaire (GPAQ) is a 16-item measure of time spent in moderate and vigorous physical activity - and sedentary behavior - in a typical week (WHO, 2012). Frequency and duration of physical activity during work (including household activities), transportation, leisure time, and time spent sitting or reclining are also assessed (WHO, 2012).

Analytical Procedure

Descriptive statistics were calculated to describe respondents' characteristics and baseline scale measures by treatment group. Scale level missing data were assessed for level and reason using Little's test for missing completely at random (MCAR) (Little, 1988) and Potthoff et. al.'s assessment of missing at random (MAR) (Potthoff, 2006). To examine whether hypothesized variables mediated the relationship between treatment conditions and perceived stress and mental health outcomes, we used composite indicator structural equation (CISE) – alpha modeling. This method uses Bayesian techniques to model potential pathways. The model structure is shown in Figure 2.

A particular advantage of CISE is the improvement in reliability due to incorporating measurement errors into the model, which serves to reduce attenuation in the estimates (McDonald et al., 2005). The CISE modeling approach creates composite variables by combining the items of each separate measurement domain into a single indicator, and then fixes a measurement error term in the model to $(1 - \text{reliability}) * \text{variance}$ (Petrescu, 2013). The resulting model (Figure 2) included two adjusting covariates (i.e., age and gender).

Mediation testing was based on the methods proposed by Brown (1997), MacKinnon (2008) and Kraemer et al. (2008), and used significant indirect effects to demonstrate mediation (Brown, 1997; Kraemer, 2008; MacKinnon, 2008). We estimated the direct, indirect (total and specific), and total effects using Bayesian estimates, with diffuse priors (non-informative) (Lee, 2007; Yanuar, 2014). Bayesian estimates were obtained by applying Markov Chain Monte Carlo (MCMC) performed through Gibbs sampler, which generates a sequence of random observations from the joint distribution of the structural parameters (Lee, 2007; Song & Lee, 2012).

Analysis of the CISE model was constructed using MPlus Version 7.4 (Muthen & Muthen, 2015). Two composite variable scores in the model, GPAQ and ESES, needed to be transformed. GPAQ distribution was positively skewed with 2% of the cases reporting extremely high levels of physical activity, which were Winzorized above the 98th percentile (Barnett & Lewis, 1994). The Winzorized distribution was assessed using the Box-Cox transformation routine to normalize the distribution. The Box-Cox routine suggested the following transformation ($Y = (\text{GPAQ} + 93.6) ^{.05}$), which subsequently reduced the skewness from 2.20 to -0.02 . The other variable requiring transformation, ESES, displayed reasonably normal distribution, but the degree of variance was considered high, which can cause convergence problems in structural models. ESES was therefore transformed by dividing by 100, which reduced the variance measure to appropriate levels.

A second CISE-alpha model was constructed to assess the indirect effects of the 6 MSES-R subscales (emotion regulation, equanimity, social skills, distress tolerance, taking responsibility and interpersonal effectiveness) on expected outcomes of mental health and perceived stress. As the purpose of this analysis was not to optimize model fit, but rather to assess mediational structure, we reported Bayesian posterior predictive p-value (PPP) (Gelman, 2004), and latent variable R-squares.

Results

Baseline Characteristics

Of the 1,197 assessed for eligibility, 605 were brought in for more intensive screening, 413 were randomized, and 390 completed the trial. Participants were primarily female (76%), white (85%), educated (76.5% completing college), and middle aged (mean age $49.6 \pm SD$ 11.6 years). There was a 94% retention rate of participants who remained for the entire length of the study. Adherence rates, however derived from self-reported practice, were remarkably high, with 79% percent of exercisers and 62% of meditators who reported 150 minutes/week practice for at least half of the 37 weeks monitored. Results indicated that our missing data met at least MAR assumption for missing data. Subsequently, missing data were imputed using expectancy maximization multiple imputation strategy (Schafer, 2002). Table 1 shows the baseline demographic and psychosocial characteristics of the study sample.

Figure 1 shows the CONSORT diagram representing the flowchart of participants. Out of the total number of individuals ($n = 1197$) who were screened by phone, 592 were excluded: 349 did not meet inclusion criteria by phone interview due to already having an established program of exercise, meditation, or a medical diagnosis that was listed in the exclusion criteria list, 162 declined to participate, 81 were listed as “other reasons”. Out of the 605 individuals that were “run-in” eligible, 192 were excluded: 58 did not meet inclusion criteria, and 134 declined to participate. Run-in tasks included in-person baseline questionnaires, at least one phone contact, self-report questionnaires at home, and a follow-up in-person appointment. Thereafter, 413 participants were randomized to each of the 3 study arms: exercise ($n = 137$), meditation ($n = 138$), and control ($n = 138$). Randomization check did not yield significant group differences at baseline in age, gender, ethnicity, education, body mass index, income, mental health, perceived stress, mindful attention, mindfulness self-efficacy, exercise self-efficacy, and global physical activity (all $p > .05$). The present analyses are based on a final sample of: exercise ($n = 109$), meditation ($n = 111$), and control ($n = 133$) due to withdrawing, dropping or not completing the class.

Aim 1. Direct effects of meditation and exercise treatment programs on outcomes of mental health and perceived stress.—Direct effect paths of the mediation model are presented in Figure 3 and Table 2. Model fit was indicated by PPP and R^2 . While PPP was <0.001 with mean Chi-square of 131.26 with 10 degrees of freedom indicating a poor fitting structure, the values of R^2 at 0.461 for PSS10 and 0.488 for SF12M, indicated reasonable predictability. A statistically significant positive direct effect of meditation on SF12M indicated that those in the meditation group reported higher mental health ($\beta^* = 0.132$) than the other study conditions post-intervention. The beta with the (*) indicates that this is a standardized parameter. While this was the only significant direct treatment effect on outcomes, the treatment conditions had other direct effects on the possible mediating variables. Significant positive direct effects of meditation were discovered on the mediating variables of MAAS ($\beta^* = 0.119$), MSES-R ($\beta^* = 0.183$), and ESES ($\beta^* = 0.163$). The exercise program indicated significant positive direct effects on all mediating variables (e.g., MAAS ($\beta^* = 0.136$), MSES-R ($\beta^* = 0.122$), ESES ($\beta^* = 0.259$) and

GPAQ ($\beta^*=0.298$). The mediating variables that had a direct effect on the outcomes were MSES-R, MAAS, and GPAQ. MSES-R had a significant negative effect on PSS ($\beta^*=-0.519$) and a significant positive effect on SF12M ($\beta^*=0.501$), while MAAS had a significant negative effect on PSS ($\beta^*=-0.155$) and GPAQ had a significant positive effect on SF12M ($\beta^*=0.130$). Additionally, significant correlations were assessed between MAAS and MSES-R ($r = 0.585$, 95% CI [0.505, 0.666]), GPAQ and ESES ($r = 0.214$, 95% CI [0.104, 0.326]), and PSS and SF12M ($r = -0.894$, 95% CI [-0.966, -0.821]) at $p < 0.05$. In sum, these results indicated that there were several significant direct treatment effects including mental health in the meditation group and mediating variables in both groups along with significant associations between analogous mediating and outcome variables.

Aim 2. Indirect effects of meditation and exercise treatment programs on outcomes of mental health and perceived stress.—Indirect effect paths of the mediation model are presented in Figure 3 and Table 2. Statistically significant indirect effects were discovered for the mediating variables of MSES-R with significant negative indirect effects on PSS10 for the meditation group ($\beta^* = -0.093$), and significant positive indirect effects on SF12 ($\beta^* = 0.089$) for the meditation group. These results indicate that MSES-R partially mediated the effect of meditation on SF12M, but fully mediated its effect on PSS10. Mediating effects of MAAS and MSES-R also emerged for exercise on PSS10, with statistically significant indirect effects of ($\beta^* = -0.019$), and ($\beta^* = -0.062$) respectively. Also, the mediators of MSES-R and GPAQ significantly mediated the relationship between exercise and SF12M, with indirect effects of ($\beta^* = 0.060$) and ($\beta^* = 0.037$) respectively. In sum, mediation results indicated that mindfulness self-efficacy (MSES-R) mediated mental health and perceived stress in the meditation group and mental health in the exercise group, whereas both mindfulness self-efficacy (MSES-R) and mindful awareness (MAAS) mediated perceived stress in the exercise group.

Aim 3. Mediation effects of MSES-R subscales to explore specialized meditation and exercise treatment effect pathways on mental health and perceived stress.—Since MSES-R is made up of six distinct factors or subscales, we explored which contributed to indirect mediation effects—none of the other two significant mediating measures included subscales. For this secondary analysis, the MSES-R sub-scale scores were entered into the model in place of the MSES-R total score. Figure 4 provides the Wald test Z-scores for the indirect effects, providing direction of effect and 2-tailed significance at $p < 0.05$. Results indicated that the sub-scales of emotional regulation, equanimity, and interpersonal effectiveness accounted for the majority of indirect influence on PSS10 for the meditation group. Emotional regulation, social skills, and interpersonal effectiveness accounted for the majority of indirect influence on SF12M for the meditation group. Equanimity and interpersonal effectiveness accounted for the majority of indirect influence on PSS10 for the exercise group, with social skills and interpersonal effectiveness accounting for the majority of indirect influence on SF12M for the exercise group.

Discussion

Previous research shows that meditation and exercise positively affect health and well-being (Eisendrath et al., 2016; Lavie et al., 2016; Rebar et al., 2015; Wielgosz et al., 2016), and in

some cases may serve as viable alternatives or adjuncts to medical treatment (Eisendrath et al., 2016; Teixeira et al., 2015). First, and in accord with previous findings (Barrett et al., 2012; Demarzo et al., 2014; Goldin, 2012; Tsafou et al., 2017), direct effect results demonstrated that membership in a mindfulness meditation group was associated with improvements in a global indicator of mental health as compared to membership in exercise or wait-list control groups. Second and also consistent with prior studies (Baer et al., 2012), indirect effect results demonstrated that mindfulness self-efficacy (MSES-R) partially mediated the relationship between meditation and mental health, yet fully mediated the relationship between meditation and perceived stress. Mindfulness measures also mediated the indirect effects of exercise training on mental health and perceived stress. Although exercise self-efficacy (ESES) did not mediate the effects of exercise training on mental health and perceived stress, an increase in global physical activity mediated the relationship between exercise training and mental health. Third, pathways through mindfulness self-efficacy sub-scales suggested that emotion regulation, equanimity, interpersonal effectiveness and social skills contributed to the indirect mediation effects found in study analyses. Mediator and outcome variables were correlated as expected, strengthening confidence in the model.

Our results are consistent with the widely-held view that mindfulness and exercise training can improve global mental health, including adaptive responses to stress (Baer et al., 2012; Branstrom et al., 2010; Nyklík & Kuijpers, 2008; van der Zwan et al., 2015). Recent studies comparing mindfulness meditation and physical exercise show that there was no difference in the effects of either intervention on attention control and mindful awareness (de Bruin et al., 2016). Further, both programs have been shown to be equally effective in reducing stress and its related symptoms (van der Zwan et al., 2015).

Significant findings from indirect effect analyses strengthened confidence in the mental health effects of mindfulness and exercise. Mindfulness training influenced a hypothesized mechanism of effect, i.e., mindfulness self-efficacy, which in turn partially explained improvements in mental health while fully explaining declines in perceived stress (Branstrom et al., 2010; Nyklík & Kuijpers, 2008). The mindfulness training, however, did not operate through a second hypothesized mediator, i.e., the mindful attention awareness (MAAS) scale, which was surprising for several reasons. First, the MAAS theoretically represents a pathway through which mindfulness training yields effects, and second, the MAAS empirically mediated mindfulness intervention effects on health outcomes in a previous analysis of a subset of these data (Zgierska, 2013). Future research is needed to understand these findings. If replicated, they suggest that awareness alone may not promote mental health, but additional skills such as emotion regulation might also be required.

Additionally, our results suggested that exercise can influence proximal outcomes or mediators that are more typically associated with participation in mindfulness training (i.e., mindful awareness and mindful self-efficacy). Exercise also promoted a proximal outcome of global physical activity, which is more commonly associated with exercise. Both measures of mindfulness and the measure of physical activity helped to mediate the exercise-mental health connection. However, exercise self-efficacy by itself was not a mechanism for either mental health improvement or stress reduction.

Mindfulness-based self-efficacy fulfilled a prominent role in mediating both meditation and exercise training program effects. Consistent with these results, existing literature highlighted links between mindfulness and several forms of self-efficacy including coping for improving self-regulation skills (Luberto, 2013), and exercise self-efficacy for improving physical activity (Gilbert, 2010). Self-efficacy has been shown to be an important component of behavior and cognitive change (Kaplan et al., 1984). Increases in self-efficacy have been associated with better illness management and lower distress for individuals who suffer from chronic conditions (Bonsaksen, 2012).

Specific components of mindfulness self-efficacy that mediated both mindfulness and exercise training effects on mental health and perceived stress were: emotion regulation, equanimity, interpersonal effectiveness and social skills. These results suggest that MBSR influences mental well-being through mechanisms that are both consistent with program theory such as awareness, acceptance, and self-management (i.e., emotion regulation and equanimity) (Brown & Ryan, 2003; Keng et al., 2011), and not as apparent in the program theory (e.g., interpersonal effectiveness and social skills). This latter theme implies that programming involving social skills and engagement, delivered concurrent with MBSR and/or exercise training, may strengthen program effects on global mental health. These results are further reinforced by similar findings that increased self-esteem and positive affect contribute to the link between exercise and quality of life (Joseph et al., 2014).

While this study relied on an experimental research design, repeated measures derived from validated scales collected prospectively, and advanced statistical methods, several limitations qualify results. For instance, participants had to fit the inclusion criteria, to be willing to be randomized to one of the three conditions, and to carry out the associated activities. These participants are not likely to be representative of the general population. Additionally, the study sample was predominantly Caucasian and well-educated, which further limits generalizability of results to Whites with high levels of educational attainments. Data from this study came from self-reported assessment measures, rather than clinical interviews, which are subject to biases such as over- or underreporting, and social desirability bias (Edwards, 1957). In addition, our sample was a relatively healthy population who qualified for the study because they experienced at least one acute respiratory infection over the past year and generated baseline scores of relevant variables within moderate to average ranges as compared to national norms. Therefore, it may have been difficult to detect direct program effects on proximal and distal outcomes due to initial scores on study measures, i.e., ceiling effects. Also, the lack of mental health study measures limited our ability to probe program effects on an array of mental health indicators. Finally, while some effect sizes in the model were statistically significant, the effect sizes were generally considered “small”. In many cases, effect sizes only explained an estimated 4% change in an outcome measure per unit change in a predictor. However, some patients experienced multiple unit changes, which may have had a substantial change in the outcome for that patient.

Given the study’s limitations and results, we recommend that future research test mindfulness and exercise programs with a sample that includes greater racial/ethnic and socio-economic diversity than our own. In addition, future trials should test the implications of combining mindfulness and exercise training programs given shared mechanisms of

effect. We expect that integrating these program types will strengthen the observed mental health effect of either single program type. Finally, based on our finding that social measures helped to mediate mindfulness program effects, mindfulness researchers might consider incorporating social components to mindfulness training. Some form of planned social activity over the course of mindfulness training may, according to our findings, enhance program effects on stress and mental health-related outcomes. Not only does this hypothesis draw on our own findings, but it is also informed by a robust body of work supporting the mental health effects associated with social engagement (Kawachi & Berkman, 2001).

From a practical standpoint, our research suggests that clinicians and patients should consider mindfulness and exercise practices as stress reducers and well-being enhancers. This assertion of course is not new, but what our study reveals is that: 1) mindfulness and exercise indeed affect mental health, and 2) mindfulness and exercise share common mechanisms of effect. These two major findings suggest that regular practice of both mindfulness and exercise may promote mental well-being.

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Fig. 1. Composite Indicator Structural Equation (CISE) model showing hypothesized direct effects of the treatment programs on expected outcomes, indirect effects on mental health (SF12) and perceived stress (PSS) and correlations between potential mediators.

Fig. 2.
Flowchart of participants

Fig. 3. Significant standardized pathway coefficients of direct effects of the treatment programs on expected outcomes, indirect effects on mental health (SF12) and perceived stress (PSS) and correlations between mediators.

Fig. 4. Indirect effects of MSES-R sub-scales of emotion regulation, equanimity, social skills, distress tolerance, taking responsibility and interpersonal effectiveness on mental health and stress using Wald test Z-scores indicating 2-tailed significance at $p < 0.05$.

Table 1.

Baseline demographic and psychosocial characteristics of the study population.

Characteristic	Meditation	Exercise	Control
Sample, n	138	137	138
Age, mean $\pm$ SD	49.2 $\pm$ 11.2	49.1 $\pm$ 11.4	50.7 $\pm$ 12.1
Male, n (%)	33 (23.9)	30 (21.9)	37 (26.8)
Female, n (%)	105 (76.1)	107 (78.1)	101 (73.2)
Nonsmokers, n (%)	132 (95.7)	128 (93.4)	127 (92.0)
Smoker, n (%)	6 (4.3)	9 (6.6)	11 (8.0)
Race, n (%)			
White/Caucasian	121 (88.3)	105 (76.6)	123 (89.1)
Non-Caucasian	15 (10.9)	25 (18.2)	12 (8.7)
More Than One Race	1 (0.7)	7 (5.1)	3 (2.2)
Ethnicity non-Hispanic, n (%)	11 (8.2)	5 (3.8)	8 (6.0)
Non-Hispanic	124 (91.9)	128 (96.2)	126 (94.0)
Hispanic	11 (8.1)	5 (3.8)	8 (6.0)
BMI, mean $\pm$ SD	29.8 $\pm$ 7.8	29.3 $\pm$ 7.0	29.0 $\pm$ 6.6
College graduate or higher, n (%)	106 (76.8)	108 (78.8)	102 (73.9)
Income > \$50,000, n (%)	85 (63.4)	79 (58.1)	85 (62.5)
Mean scores at baseline, n $\pm$ SD			
SF12: Mental Health	48.0 $\pm$ 10	47.9 $\pm$ 10.4	47.6 $\pm$ 9.9
PSS: Perceived Stress	13.1 $\pm$ 6.4	13.3 $\pm$ 6.6	12.4 $\pm$ 5.9
MAAS: Mindfulness Attention	4.1 $\pm$ 0.8	4.3 $\pm$ 0.8	4.3 $\pm$ 0.7
MSES: Mindfulness Self-Efficacy	97.6 $\pm$ 15.7	97.3 $\pm$ 14.7	96.8 $\pm$ 14.6
ESES: Exercise Self-Efficacy	112.5 $\pm$ 38.3	112.4 $\pm$ 38.6	116.0 $\pm$ 38.8
GPAQ MET-hrs/wk	730.0 (240.0–1940.0)	560.0 (160.0–1320.0)	1020.0 (320.0–2400.0)

Abbreviations: SD = standard deviation, BMI = body mass index (weight/height²), SF12 = medical outcomes study short form, PSS = perceived stress scale, MAAS = mindful attention awareness scale, MSES = mindfulness self-efficacy scale, ESES = exercise self-efficacy scale, GPAQ = global physical activity questionnaire

Table 2.

Total, direct and indirect (total and specific) effect paths and correlations for mindfulness and exercise programs.

Direct Effect Paths					
	Unstandardized Estimates¹	Posterior SD	Unstandardized 95% CI²	P	Standardized Estimates³
MAAS --> PSS	1.247	0.523	[-2.234, -0.177]	0.014 *	-0.155
MSES --> PSS	-0.33	0.044	[-0.419, -0.247]	0.00 *	-0.519
ESES --> PSS	-0.657	0.881	[-2.316, 1.105]	0.454	-0.04
GPAQ --> PSS	-7.006	3.917	[-14.809, 0.497]	0.072	-0.098
MAAS --> SF12	1.754	0.856	[0.117, 3.473]	0.036 *	0.148
MSES --> SF12	0.469	0.072	[0.327, 0.603]	0.00 *	0.501
ESES --> SF12	1.089	1.436	[-1.673, 3.994]	0.454	0.045
GPAQ --> SF12	13.663	6.316	[1.135, 25.894]	0.036 *	0.13
Meditation --> PSS	-0.623	0.697	[-1.985, 0.746]	0.372	-0.046
Exercise --> PSS	1.302	0.713	[-0.096, 2.708]	0.072	0.097
Age --> PSS	-0.047	0.025	[-0.095, 0.005]	0.068	-0.085
Sex --> PSS	-0.744	0.693	[-2.098, 0.628]	0.28	-0.05
Meditation --> SF12	2.658	1.151	[0.414, 4.910]	0.02 *	0.132
Exercise --> SF12	-0.199	1.185	[-2.445, 2.198]	0.866	-0.01
Age --> SF12	0.057	0.041	[-0.023, 0.139]	0.174	0.071
Sex --> SF12	-0.064	1.134	[-2.256, 2.177]	0.952	-0.003
Meditation --> MAAS	0.202	0.098	[0.004, 0.388]	0.04 *	0.119
Exercise --> MAAS	0.229	0.096	[0.036, 0.411]	0.018 *	0.136
Age --> MAAS	0.013	0.003	[0.008, 0.020]	0.00 *	0.196
Sex --> MAAS	0.269	0.095	[0.088, 0.459]	0.004 *	0.147
Meditation --> MSES	3.894	1.288	[1.344, 6.355]	0.002 *	0.183
Exercise --> MSES	2.571	1.296	[0.003, 5.088]	0.042 *	0.122
Age --> MSES	0.179	0.048	[0.095, 0.277]	0.00 *	0.209
Sex --> MSES	-2.341	1.2	[-4.638, 0.056]	0.056	-0.101
Meditation --> ESES	0.134	0.047	[0.046, 0.228]	0.006 *	0.163
Exercise --> ESES	0.21	0.046	[0.121, 0.301]	0.00 *	0.259
Age --> ESES	0.003	0.001	[0.001, 0.006]	0.006 *	0.103
Sex --> ESES	0.056	0.044	[-0.029, 0.141]	0.198	0.063
Meditation --> GPAQ	0.001	0.012	[-0.022, 0.023]	0.92	0.007
Exercise --> GPAQ	0.056	0.011	[0.033, 0.078]	0.00 *	0.298
Age --> GPAQ	0.001	0	[0.00, 0.002]	0.002 *	0.145
Sex --> GPAQ	0.037	0.011	[0.016, 0.059]	0.002 *	0.178
Total Effect Paths					

Direct Effect Paths					
	Unstandardized Estimates ¹	Posterior SD	Unstandardized 95% CI ²	p	Standardized Estimates ³
Meditation --> PSS	-2.249	0.805	[-3.768, -0.598]	0.009 *	-0.166
Exercise --> PSS	-0.376	0.803	[-1.968, 1.179]	0.638	-0.028
Meditation --> SF12	5.005	1.3	[2.291, 7.406]	0.000 *	0.249
Exercise --> SF12	2.437	1.291	[-0.112, 4.950]	0.066	0.123
Correlations					
MAAS <--> MSES	4.114	0.473	[3.215, 5.045]	0.00 *	0.585
ESES <--> GPAQ	0.006	0.002	[0.003, 0.010]	0.00 *	0.214
SF12 <--> PSS	-28.05	2.916	[-33.798, -22.545]	0.00 *	-0.894

Indirect Effect Paths					
	Unstandardized Estimates ^a	Posterior SD	Unstandardized 95% CI ^b	p	Standardized Estimates ^c
Meditation --> MAAS --> PSS	-0.231	0.169	[-0.607, 0.016]	0.054	-0.017
Meditation --> MSES --> PSS	-1.267	0.461	[0.001, -2.187]	0.002 *	-0.093
Meditation --> ESES --> PSS	-0.077	0.129	[-0.364, 0.163]	0.456	-0.006
PSSMeditation --> GPAQ --> PSS	-0.004	0.093	[-0.210, 0.179]	0.928	0
Exercise --> MAAS --> PSS	-0.26	0.176	[-0.649, 0.000]	0.03 *	-0.019
Exercise --> MSES --> PSS	-0.839	0.446	[0.021, -1.730]	0.042 *	-0.062
Exercise --> ESES --> PSS	-0.378	0.194	[0.227, -0.536]	0.464	-0.01
Exercise --> GPAQ --> PSS	1.302	0.235	[0.036, -0.870]	0.074	-0.028
Meditation --> MAAS -> SF12	0.318	0.259	[-0.058, 0.888]	0.074	0.016
Meditation --> MSES --> SF12	1.787	0.668	[0.490, 3.093]	0.002 *	0.089
Meditation --> ESES --> SF12	0.127	0.21	[-0.234, 0.610]	0.458	0.006
Meditation --> GPAQ --> SF12	0.01	0.175	[-0.348, 0.376]	0.922	0.001
Exercise --> MAAS --> SF12	0.36	0.271	[-0.036, 0.962]	0.052	0.018
Exercise --> MSES --> SF12	1.185	0.638	[-0.067, 2.433]	0.042 *	0.06
Exercise --> ESES --> SF12	0.215	0.316	[-0.361, 0.896]	0.454	0.011
Exercise --> GPAQ --> SF12	0.743	0.392	[0.056, 1.591]	0.036 *	0.037
Total Indirect Effect Paths					
Meditation --> PSS	-1.629	0.537	[-2.719, -0.628]	0.002 *	-0.12
Exercise --> PSS	-1.662	0.572	[-2.785, -0.566]	0.004 *	-0.123
Meditation --> SF12	2.334	0.778	[0.834, 3.860]	0.002 *	0.117
Exercise --> SF12	2.614	0.857	[0.997, 4.360]	0.002 *	0.131

Abbreviations: *SD* = *standard deviation*, SF12 = medical outcomes study short form, PSS = perceived stress scale, MAAS = mindful attention awareness scale, MSES = mindfulness self-efficacy scale, ESES = exercise self-efficacy scale, GPAQ = global physical activity questionnaire

*
2-tailed significance at $p < 0.05$

¹
unstandardized posterior mean

²
unstandardized 95% credible interval

³
standardized posterior mean

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